

§22. Propagation of Nonlinear Magnetosonic Waves and Associated Particle Acceleration

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Nonlinear magnetosonic waves such as solitons and shocks have been studied by many authors, and those studies have been applied to plasma heating, particle acceleration, etc. Recently it has been found that the presence of multi ion species provides many interesting phenomena in both wave propagation [1,2] and particle acceleration [3]. We here mainly describe the nonlinear wave propagation.

In a plasma containing two ion species, the magnetosonic wave is split into two modes; we call them high- and low-frequency modes. Although the high-frequency mode has a finite cut-off frequency, which is of the order of an ion cyclotron frequency, it has been shown that both of the modes can be described by KdV equations. The KdV equation for the low-frequency mode is valid when the characteristic wavenumber k is much smaller than the wavenumber k_c ; its magnitude is $k_c \sim 10^{-2} \times \omega_{pe}/c$. The amplitudes, therefore, must be small. On the other hand, the KdV equation for the high-frequency mode is valid for the amplitudes $(m_e/m_i)^{1/2} \ll \epsilon \ll 1$. These restrictions can be understood from the dispersion curves, if we note that for KdV solitons we have a relation that $\epsilon^{1/2} \sim k$. The soliton width of the low-frequency mode is of the order of the ion skin depth, while that of the high-frequency mode is of the order of the electron skin depth.

To study nonlinear dynamics of magnetosonic waves in a two-ion-species plasma in more detail, we have carried out computer simulations based on a three-fluid model, in which fluid dynamics of light ion, heavy ion, and electron are coupled with Maxwell equations. We consider waves propagating in the direction perpendicular to a magnetic field. As initial wave profiles we set solitary wave solutions obtained from the KdV equations. We then observed their space-time evolution.

Figure 1 shows how large-amplitude low-frequency mode behaves, which the above nonlin-

ear theory cannot predict. In this figure magnetic field profiles at various times are plotted. It shows that a large-amplitude pulse quickly steepens, although its initial profile is a solitary wave solution of the low-frequency mode. After the steepening, short-wavelength pulses are generated and go ahead of the original long-wavelength pulse. From observations of wavelengths and propagation speeds of these short wavelength pulses, it has been shown that these pulses are solitary waves of the high-frequency mode; from the large-amplitude pulse of the low-frequency mode solitary waves of the high-frequency mode were produced. In the nonlinear dynamics the low- and high-frequency modes are coupled.

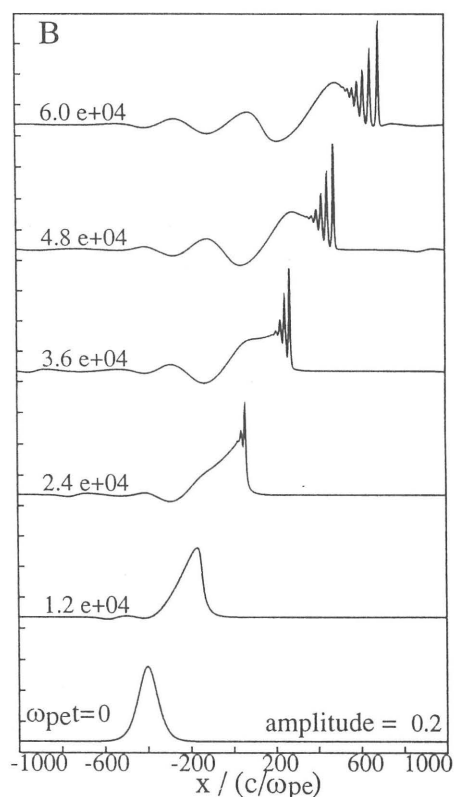


Fig. 1. Evolution of nonlinear magnetosonic waves. Initially, a large-amplitude $(\delta B/B_0)$ solitary wave solution for the low-frequency mode is imposed.

References

- 1) Toida, M. and Ohsawa, Y., J. Phys. Soc. Jpn. **63** (1994) 573.
- 2) Toida, M., Ohsawa, Y., and Jyounouchi, T., Phys. Plasmas **2** (1995) 3329.
- 3) Toida, M. and Ohsawa, Y., J. Phys. Soc. Jpn. **64** (1995) 2036.